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Sustainability Practices in Industrial Production

A Comparative Study of Selected Manufacturing Companies

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ABSTRACT:

The purpose of this thesis is to examine and compare the sustainability practices executed in the three leading manufacturing companies operating namely ABB, Wärtsilä, and Valmet. This thesis uses a qualitative approach. It analyses various reports published between 2022 and 2024 by each company. The analysis is based on four main frameworks which are Triple Bottom Line, Circular Economy, Lean-Green Manufacturing, and Environmental, Social, and Governance.

The findings show that all three companies have made strong progress in reducing their environmental impact. ABB has reduced its Scope 1 and 2 emissions by 78% since 2019. Wärtsilä has reduced its material use by 45% since 2018. Valmet has achieved science-based targets approved by the Science Based Targets initiative (SBTi), including a 49% reduction in emissions. In terms of social performance, all three companies show strong safety results and clear improvements in gender diversity. Women now hold approximately 21–22% of management positions in each company. However, their approaches to circular economy practices differ. ABB uses a clear, target-based portfolio assessment to measure circularity. Wärtsilä focuses on improving resource efficiency in its operations to achieve circular results. Valmet promotes ecosystem-based innovation through its beyond Circularity programme.

The thesis concludes sustainability is an integrated strategic priority among these companies. It supports financial performance instead of constraining it. This thesis provides a practical comparison across different companies and helps to address a gap in existing literature.

KEYWORDS: Sustainability; Sustainable Manufacturing; Triple Bottom Line (TBL); Circular Economy (CE); Environmental, Social, and Governance (ESG); Comparative Case Study; Industrial Production; ABB; Wärtsilä; Valmet

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Abbreviations

ABB – Asea Brown Boveri (company name)

CE – Circular Economy

CO_2 – Carbon Dioxide

CO_2e – Carbon Dioxide Equivalent

CSRD – Corporate Sustainability Reporting Directive

EMS – Environmental Management System

ESG – Environmental, Social, and Governance

EU – European Union

GHG – Greenhouse Gas

GRI – Global Reporting Initiative

ILO – International Labour Organization

IoT – Internet of Things

ISO – International Organization for Standardization

KPI – Key Performance Indicator

LTIFR – Lost Time Injury Frequency Rate

MWh – Megawatt Hour

R&D – Research and Development

SASB – Sustainability Accounting Standards Board

SBTi – Science Based Targets initiative

SDG – Sustainable Development Goal

SGRL – Smart, Green, Resilient, and Lean

SME – Small and Medium-sized Enterprise

STEM – Science, Technology, Engineering, and Mathematics

TBL – Triple Bottom Line

TCFD – Task Force on Climate-related Financial Disclosures

TRIF – Total Recordable Injury Frequency

UN – United Nations

1 Introduction

This chapter begins with a paradox that the same industrial production systems that have fuelled economic growth, technological advancements, and prosperity are today at the forefront of the climate change problem, depletion of resources, and society's growing demand for responsible business behaviour. Across the globe, the manufacturing sector is facing growing pressure from governments, investors, customers, and the wider community to move past the conventional linear "take, make, dispose" paradigm and integrate sustainability into its offerings and operations (Karuppiah et al., 2024). Instead of treating sustainability reporting as an 'edge' issue, the value-creating organizations are now transforming their approach towards product design, the use of energy, material use, stakeholder engagement practices, and Triple Bottom-Line activities. In this context, ABB, Wärtsilä, and Valmet are three globally active Finnish industrial companies that offers a compelling setting to explore how sustainability is being translated from high-level ambitions into production practices.

1.1 Background of Study

The manufacturing industry is at the heart of economic development globally, with significant contributions but also bears the blame for the considerable degradation of the environment and natural resources through emissions, waste, and the unsafe or inequitable conditions at workplaces. Industry represents more than one-third of the GHG emissions around the world and about 38% of the energy consumed; thus, manufacturing companies are increasingly under the lens of regulators, customers, investors, and local communities (Bello-Pintado et al., 2023).

Accordingly, the reaction has been that sustainability moved from the peripheral to becoming a strategic imperative during industrial production. Modern sustainability discourse in manufacturing generally operates through the lens of the triple bottom line (TBL), which encompasses environmental, economic and social performance (Tiuncika

& Bormane, 2024). The ambition of sustainable manufacturing is to optimize energy consumption and functions, minimize waste and pollutants, promote worker health, safety and social responsibility as well as product performance/outcome across the entire life-cycle process within supply chain mechanism while remaining competitive without diminishing profitability.

However, several organizations still find it challenging to operationalize sustainability in a comprehensive manner because of financial constraint, lack of definite benchmark and indicators and difficulty integrating sustainability into strategy and operations (Purushothaman et al., 2025). At the same time, international agendas such as the UN Sustainable Development Goals (SDGs) have multiplied expectations that manufacturing firms contribute to climate action, responsible consumption and production, decent work, and reduced inequalities. Empirical research on sustainability oriented manufacturers has demonstrated that they are more and more implementing a wide range of sustainable business practices ranging from energy and emissions management, over workplace well-being, to local embeddedness, and stakeholder engagement and that they have the potential for impacting upon a vast set of the SDGs (Bonfanti et al., 2022).Many of these practices are voluntarily embraced and incorporated into sustainable business models and value propositions instead of responding only to regulation (Bonfanti et al., 2022).

To this environment, Industry 4.0 and digital transformation come as an additional layer. Emerging technologies, including big data analytics, industrial internet of things (IoT), robotics and intelligent systems have been instrumental in the development of green processes and sustainability-related results such as energy reduction, emission abatement, resource utilization optimization as well as cost savings, productivity improvements and work safety enhancement. Such frameworks have been recently extended to advocate for the integration of these technologies with circular economy principles, sustainable supply chain management and new business models, that support transitioning towards more sustainable production systems or even human centric Industry 5.0

oriented systems (Tiuncika & Bormane, 2024). However, several limitations still exist. It is further underscored that in manufacturing enterprises the social dimension of sustainability (worker wellbeing, equality and community resilience) are still considered only an afterthought as for making economically sustainable businesses for centuries to come, but up to date social issues have become unequivocally central to guarantee their long term development, at least equally important than environmentally related measures (Opoku & Li, 2025).

Differences in the drivers and patterns of sustainability adoption are also striking that is stakeholder pressures vary among groups (customers, regulators, NGOs, employees), and firms react heterogeneously to these pressures when adopting internal monitoring, external monitoring and collaborative sustainability practices (Karuppiah et al., 2024). Moreover, there is no consensus perspective on a set of indicators or tools to evaluate sustainable manufacturing performance, this impedes benchmarking and cross-company comparisons. Against this backdrop, there exist multinational technology and equipment suppliers such as ABB, Wärtsilä and Valmet who engage in energy and material-intensive value chains (power generation systems, maritime and energy solutions, pulp and paper production facilities as well process industries). Manufacturing-oriented research indicates that such firms are typically perceived as benchmark players with respect to sustainability, particularly when they behave as multinational enterprises and embed digital solutions, sustainable supply chain actions and unambiguous articulation of sustainability value within their strategies. Such comparative, company-level research can hence yield useful information on how different industrial companies design and manage sustainability practices in their production systems, ensure that they combine TBL targets and match well with global standards like the SDGs.

Regardless of the growing practice of sustainability reporting in the manufacturing industry, no comparative studies have investigated the execution of the production-based sustainability initiative by companies. The knowledge of similarities and differences

between companies can help to create an understanding of the best practices, detect voids and reveal the information in both academic literature and practice.

1.2 Research gaps and aim

While there are few research available concerning sustainability practices in manufacturing sector but the through comparisons-based research on leading companies are scarce. Especially regarding North European based manufacturing companies like ABB, Wärtsilä, and Valmet. Even among the available research, some researches are oriented to large surveys of many anonymous companies and some are oriented in single case-study. High quality comparative studies comparing sustainability strategies, operational actions and directly measured performance are rare so far, particularly in heavy industry and capital goods industries (Deirmentzoglou et al., 2026). This leaves a gap for research that systematically contrasts with a few leading companies explaining differences and similarities in their sustainability approaches.

The second gap is the integration between sustainability practices; its measurement systems and SDG alignment is still limited. Studies of manufacturing firms in Europe and elsewhere show that sustainability indicators are often few heavily skewed toward economic metrics, and environmental and social indicators are frequently measured mainly for legal compliance (Bonfanti et al., 2022). Even when companies map their strategies to the UN SDGs, there is rarely a systematic link between concrete production practices and reports regarding SDG contributions (Deirmentzoglou et al., 2026). Studies on operationalizing sustainable business models indicate that firms have the potential to contribute to several SDGs, while the details of such contributions, their consistency and comparability across firms is not well understood (Bonfanti et al., 2022). It is also difficult to find comparative work across large manufacturers that specifically address how they design and utilize sustainability metrics, as well as SDG mappings (Bonfanti et al., 2022).

A third gap is the insufficient development of strong approaches and evidence to deal with trade-offs and interdependencies between sustainability goals within manufacturing. The literature on trade-offs between sustainability goals demonstrates that companies struggle with identifying and managing the tensions between economic, ecological, and social objectives at work level as well as within the value chain (Koch & Sauer, 2024). Although conceptual frameworks and paradox theory have been proposed, there are still very few practical methods or case-based studies showing how real manufacturers systematically identify, evaluate, and resolve conflicts such as cost vs. emissions, throughput vs. worker wellbeing, or local community impacts vs. global efficiency (Koch & Sauer, 2024). This is particularly relevant in large industrial companies with complex multi stakeholder trade-offs. Some studies rely on management self-reports and lack external stakeholder perceptions or the evidence of actual impacts on workers and the community. There is a need for multi stakeholder, multi company studies that link internal practices and reporting with external consequences and perceptions, particularly in high impact manufacturing sectors.

The aim of this thesis is to analyse qualitatively the sustainability practices of ABB, Wärtsilä, and Valmet in their industrial production activities. Firstly, this thesis aims to detail how each company integrates sustainability into its production operations. Secondly, identify the key similarities and differences in their approaches and thirdly evaluate how these initiatives correspond with prominent sustainability frameworks such as the Triple Bottom Line (TBL), Circular Economy (CE), and Environmental, Social, and Governance (ESG) criteria. By doing so, this thesis will also consider the degree to which each firm goes beyond basic legal compliance in pursuing more proactive sustainable production and sustainable operations management, and what configurations of practices appear most mature-or most limited-compared with patterns observed in other manufacturing companies. Meanwhile the thesis will examine how these practices are tactically framed and accounted. It will address to which extent ABB, Wärtsilä and Valmet integrate their production related practices towards the SDGs, either explicitly or implicitly based on measuring and communicating sustainability performance relying on metrics systems

and frameworks. Notably, special emphasis will be put on how the three companies frame their metrics in terms of environmental, social and economic pillars; how they identify and manage internal tradeoffs across cost, efficiency, environmental impact and social outcomes; and what remains uncovered or biased for e.g., underpinning performance through an over reliance on economics. (Viles et al., 2023). The thesis compares these and other issues to explain main apparent similarities and differences between the businesses, as well as to identify evident combined improvement potential and impressive benchmarking indication for more sustainable industrial production in like-producing companies

1.3 Research Question and Objectives

The preceding discussion of research gaps highlights the need for a focused, comparative study of sustainability implementation among leading industrial manufacturers. To address these gaps systematically, this thesis is guided by the following primary research questions:

1. How do ABB, Wärtsilä, and Valmet integrate sustainability practices in their production operations?
2. What are the similarities and differences among the companies' production sustainability initiatives?
3. How do these initiatives align with established sustainability frameworks (TBL, CE, ESG)?

Answering these questions is important because this will provide an in-depth understanding of operational sustainability practices of industry leaders. It will also help to identify the effective strategies and common challenges in the industrial manufacturing sector.

To answer the above questions analytically following research objectives have been outlined:

1. To identify the present environmental, social, and economic sustainability practices executed by ABB, Wärtsilä, and Valmet in their industrial production.
2. To analyze and compare the similarities, differences and potential areas for improvement of three companies from the identified sustainability practices.
3. To evaluate the alignment of ABB, Wärtsilä and Valmet sustainability practices with the fundamental principles of Triple Bottom Line (TBL), Circular Economy (CE) and Environmental, Social and Governance (ESG) frameworks.

This thesis aims to address these questions from empirical as well as theoretical perspectives. Theoretically, this paper is grounded in sustainability reporting frameworks, triple bottom line concept and stakeholder theory to contextualize and explain the companies' activities.

1.4 Scope and Limitations

1.4.1 Scope of the Study

This thesis focuses on the sustainability practices of case companies from 2022 to 2024. This thesis analyses how these manufacturing companies adapt sustainable practices to the manufacturing operations under four theoretical framework that is TBL, CE, Lean-Green Manufacturing and ESG. The thesis analyses published documents by case companies. These include sustainability reports, annual reports, integrated reports, and other relevant publications downloaded from the official websites of each company. It does not include primary data such as interviews or site visits. The objective is to identify, compare, and evaluate the sustainability practices of the three companies, focusing on environmental, social, and economic performance.

1.4.2 Limitations of the Study

There are few limitations in this thesis. The first limitation is that this thesis any includes the analysis of three companies. So, the findings of this thesis cannot be generalized to all the manufacturing sectors. Second this thesis is based on the case companies published reports so the data of report may be selective or biased by the case companies. Third, the three companies had used different reporting frameworks and different baseline years for their sustainability metrics, which made direct quantitative comparison difficult. So for the easy comparison this thesis had described the direction of progress rather than exact showing all the numerical comparison.

1.5 Structure of the Thesis

The structure of the thesis is as follows:

Chapter 1 introduces the research topic and presents the background of the study. This chapter shows the research gaps and presents the research questions with the objectives with the scope of this thesis and limitations of the thesis.

Chapter 2 reviews existing literature on sustainability in industrial production, sustainable manufacturing practices, sustainability reporting, and previous empirical studies.

Chapter 3 presents the four theoretical frameworks used in this thesis that are Triple Bottom Line (TBL), Circular Economy (CE), Lean-Green Manufacturing, and Environmental, Social, and Governance (ESG) frameworks and introduces the conceptual framework of this thesis.

Chapter 4 describes the research methodology, including the research approach and design, data sources, company selection criteria, data collection procedures, thematic and content analysis methods, and considerations of reliability, validity, and research ethics.

Chapter 5 presents the results and findings from the comparative analysis of ABB, Wärtsilä, and Valmet, including sustainability principles in practice, cross-comparison of convergent and divergent patterns, and thematic and empirical findings.

Chapter 6 discusses the findings with respect to the four theoretical frameworks.

Chapter 7 concludes the thesis with a summary of findings, theoretical and practical contributions, managerial recommendations, limitations of the study, suggestions for future research, and concluding remarks.

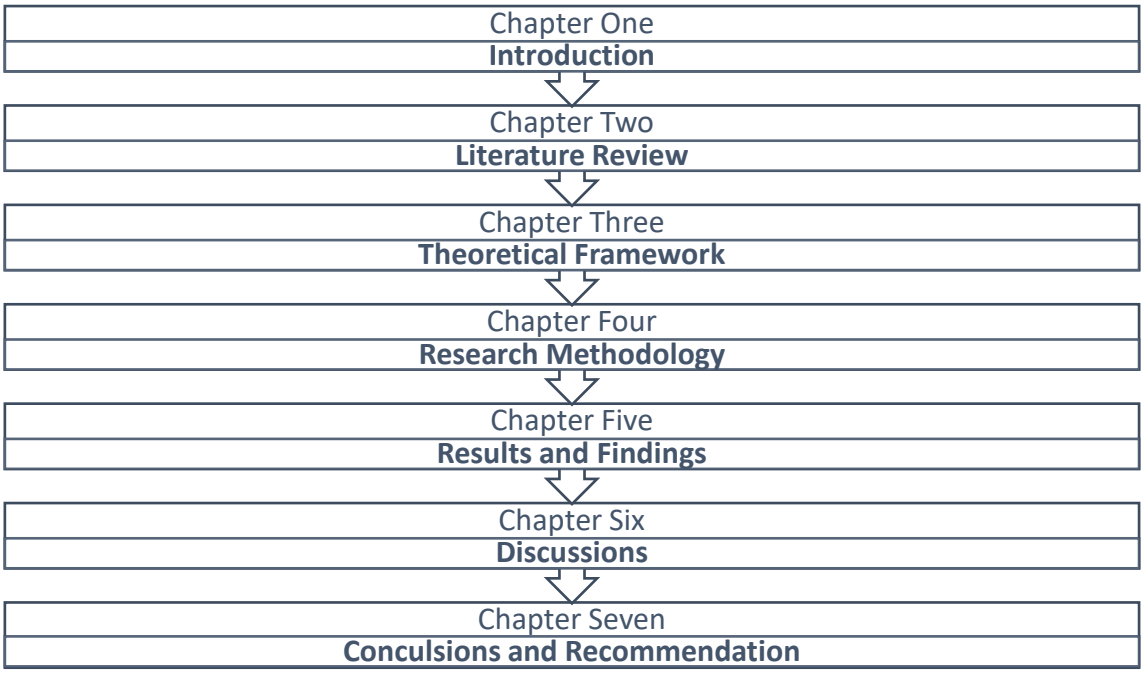

Figure 1. Structure of the thesis

2 Literature Review

In today's world, sustainability has become a major concern for manufacturing companies. Industries are facing increasing pressure from governments, their customers and global society to reduce their harmful environmental impact while remaining economically viable (Bello-Pintado et al., 2023). Today only the manufacturing sector contributes 21% of global emissions and 35% of energy consumption of the world (UNIDO, 2025). So, this chapter reviews existing literature on sustainability practices in industrial production and is focused on how companies are adopting sustainable manufacturing, the role of their management and previous research related to this field.

2.1 Sustainability in Industrial Production

According to Bonfanti et al., (2023), The concept of sustainable development was defined by the World Commission on Environment and Development and is defined as those developmental activities that fulfil the requirements of today without negotiating the ability of future generations to fulfill their needs. In manufacturing, this concept has been utilized by triple bottom line approach. TBL considers three dimensions that is economic profit, social equity, and environmental protection. So, global manufacturing companies must balance these three aspects when they design and implement their production processes. Viles et al. (2023) explain that sustainable production means the processes of creating economically viable goods through non-polluting, conserving energy and natural resources that are safe for employees and communities. This definition has evolved over time and now this definition also includes connections to circular economy principles and Industry 4.0 technologies. The circular economy means those methods which focus on eliminating waste production and reusing it. While Industry 4.0 uses modern digital technologies to make production more efficient and sustainable.

According to Bello-Pintado et al. (2023), different stakeholder groups influence how the companies adopt their sustainability practices. Their thesis shows that customers'

interest in sustainability and the decisions of top management have the strongest impact on whether manufacturing plants become more sustainable or not. Interestingly, they also concluded that shareholders, government regulations and non-governmental organizations have less direct influence on the company's daily sustainability decisions. This suggests that management and employees that conduct daily operations matter most for actual implementation of sustainability.

2.2 Development of Sustainable Production Practices

Sustainable manufacturing has evolved from just a simple pollution control systems to a necessary ideology of the production system. Karuppiah et al. (2024) performed a systematic review of 89 articles published from 2012 to 2022. Karuppiah et al. (2024) found the six key approaches for sustainable manufacturing were lean manufacturing, renewable energy adoption, green manufacturing, life cycle assessment, zero waste manufacturing, and circular economy models. Idea of Lean manufacturing started from the Toyota Production System which focused on the elimination of waste during production processes. Karuppiah et al (2024) observes that despite lean practices assist waste reduction and efficient work processes, all sustainability problems would not be resolved naturally. Some researchers even argue that lean manufacturing mainly improves environmental and operational performance, but they neglect social aspects especially like wellbeing of employees. However, others argue that when lean is combined with other sustainability goals, it can deliver broader benefits.

Green manufacturing emerged as companies' idea to reduce their ecological impact. It adopts practices such as using environmentally friendly materials, reducing energy consumption, and minimizing the use of toxic substances. Opoku and Li (2025) found that in manufacturing companies, green manufacturing practices positively influence both operational performance and sustainable performance of the company. Their research in Ghana showed that companies that adopts green practices drastically improves their product quality, their operational efficiency, and environmental outcomes.

The circular economy model represents the most recent development in sustainable manufacturing. Bonfanti et al. (2023) studied manufacturing companies in Italia and found out that they implement circular economy principles through their product innovation, while designing their products for durability and reuse and offered the repair services to extend product life. They also found out that some companies inspire their employees to use cycles while coming to work. Regardless of these examples, Karuppiah et al. (2024) notices that circular economy adoption remains limited.

2.3 Sustainability Reporting in the Manufacturing Sector

Companies have increased their criteria and activities on sustainability practices demonstrate their accountability to their stakeholders. Viles et al. (2023) developed a framework of 39 indicators that measured the sustainable production of the manufacturing companies. Vile carefully selected few indicators from existing literature and validated it through the interview with academic experts and finally created those indicators. The indicators cover the criteria of environmental aspects such as energy consumption, use of water and waste management. The social aspect of that indicator includes safety of employees and community engagement. The economic aspect of that indicator includes operating costs of the company and investments of the companies in sustainable technologies.

One important contribution of Viles et al. (2023) is the use of a Sankey diagram. This diagram shows the relation between United Nations Sustainable Development Goals (SDGs) and the company's sustainability indicators. Their analysis revealed that manufacturing activities contribute most significantly to SDG 12 that is responsible for consumption and production of the company, SDG 8 that shows decent work and economic growth. And SDG 9 that indicates industries innovation and infrastructure. The visual representation from this Sankey diagram helped the companies to understand their operational measurements with respect to broader global objectives.

However, only reporting does not guarantee real sustainability improvements for the company. According to Bonfanti et al. (2023), some companies may engage in SDG washing which is selectively reporting of information of the company while neglecting substantive sustainability improvements. So, this implies only relying on the reports published by the corporate will not provide actual information on sustainability practices. But one should focus on the actual practices conducted by the company. So, the actual challenge for researchers is to understand what companies do regarding sustainable practices not just what they claim to do in their sustainability reports.

2.4 Role of Industrial Management in Sustainable Operations

As stated briefly in 2.3, management has a huge role in determining whether the sustainability initiatives in a company will succeed or fail. Bello-Pintado et al. (2023) found that top management pressure significantly influences the implementation of internal sustainability practices, monitoring of suppliers, and overall implementation success. Their research across 330 manufacturing plants in 15 countries showed that when top managers are committed to environmental responsibility, companies are more likely to implement meaningful sustainability practices.

This shows an important thing that the difference between proactive and reactive leadership is crucial. Proactive leaders anticipate that sustainability challenges are necessary for the environment. So, they voluntarily adopt the practices in their company rather than following the government's regulations. They integrate sustainability into their core business strategy. Reactive leaders only adopt when the government regulates, or customer demands it. Often leading to superficial changes. Opoku and Li (2025) found that proactive manager leading in green manufacturing practices generate stronger performance outcomes than reactive manager whose approaches are driven mainly by external compliance.

Supply chain management also has a significant impact on sustainability. Bello-Pintado et al. (2023) distinguish between two kinds of external practices that suppliers should be monitored whether they had met the sustainability requirements and enforcement or collaboration with suppliers to improve the sustainability. From the research it was analyzed that customer pressure plays an important role for promoting both practices. So, it was found that if the company wants to achieve real sustainability, then it should have genuine intentions.

Integration of corporate strategy is another important dimension. Bonfanti et al. (2023) conducted a case study of 12 Italian manufacturing companies which showed that out of the successful sustainability-oriented companies, those with clear sustainable value propositions outperform the rest. These companies integrate their sustainability in marketing, human resources and information systems. Their employees believe that sustainability is not extra activity but a necessity for environment. This cultural integration helps companies to sustain sustainability efforts over the long run.

2.5 Previous Empirical Studies on Production Sustainability

Many researchers have published remarkable research by analyzing the sustainability practice using different methods. For example, Bello-Pintado et al. (2023), conducted one of the largest research projects in Europe, America, and Asia. They collected data from 330 manufacturing plants from 15 countries. Their research covered analysis of machinery, electronics, and automotive components of the company. During their research they found out that top management, employee and customer were the responsible for the adaptation of sustainability practices in company. The study found that stakeholder pressures influence sustainability practices in both developing and developed countries. This finding supports the convergence perspective that explains globalization leads to the adoption of similar practices across different nations.

Bonfanti et al. (2023) took a different approach. They conducted in-depth interviews with managers from 12 Italian manufacturing companies which were operating in diverse sectors. That includes food and beverages, wood processing, metal smelting, electronics, pharmaceuticals, rubber and plastics, and textiles. Their qualitative approach revealed the actual number of companies that implemented real sustainability. The researchers found that the companies have provided attention to employee well-being leading to social sustainability. This finding was quite opposite with the previous research findings which extracted the conclusions of environmental sustainability. They also found that local communities and companies' stakeholders were also involved in sustainment of ecosystems. Opoku and Li (2025), surveyed 285 managers working at 5,329 manufacturing businesses in Ghana. The companies they selected for the survey were basically food/beverage, wood and metal industries. Before the survey the researcher's hypothesis was that these companies were commented on green management. But the findings were completely different because only improvements in operational, environmental and economic do not automatically make the company's social performance better. Accordingly, those companies who had their operational, environmental, and social performance had awful economic performances.

Karuppiah et al. (2024) used bibliometric analysis for their research. They collected 89 research articles on sustainable manufacturing that were published between 2012 and 2022 and examined it. They noticed that the research conducted was hugely different depending on the industrial sector. They found that in automotive sector the research was conducted more because of regulatory requirements. Second, most research conducted in was electronics sector. During their research they analyzed that CE were given more priority during the manufacturing research done in Europe. In developing countries, the lean- green were provided with more priorities. So, a clear pattern can be seen that geographical variation priorities sustainable practices.

Viles et al. (2023) came into conclusions that automotive and electronics industries quickly adopted sustainable practices, but machinery industries had hard time adopting

it. This may be because of their own customers' expectations and less competition they are facing. The pharmaceutical and chemical industries faced the challenge of managing hazardous materials. Because of this, it can be concluded that they need specific indicators to measure and reduce toxic substances. These differences between these industries highlight that sustainability practices must be specific for each sector. A strategy that works well for one industry may not work well for another.

2.6 Summary and Identified Research Gap

This literature review has examined the main themes related to sustainability practices of manufacturing sector. Firstly, pressure from stakeholders seems to be a driving force towards the practice of sustainability. It is confirmed that it is the customers, top management, employees who are the major force pushing whether and how sustainability practice should be implemented. Secondly, sustainable manufacturing has evolved from simple thought on pollution control to other strategies. Now, it includes visions such as lean production, green practices, and circular economy models. Thirdly, although sustainability reporting has become common even though it does not always show what companies do behind the reports. This raises concerns about greenwashing and SDG washing. Fourthly, regarding management commitment the proactive leadership is essential for successful sustainability implementation. Fifth, empirical research across different industries shows both shared trends and important differences in the ways that companies apply sustainability practices.

Despite these contributions from above literature important research gaps remain. Most studies had focus on sustainability practices only in one country or one company that limits the understanding of differences between those organizations within the same context. Although Bello-Pintado et al. (2023) had carried out multinational research still their study examined overall patterns rather than detailed comparisons between individual companies. Contrarily, Bonfanti et al. (2023) had conducted detailed qualitative findings but had only focused on Italian companies. Opoku and Li (2025) provided useful

evidence from Ghana but concentrated only on a single developing country. Since there are very less comparative research on sustainability practices among specific manufacturing companies operating in Finland. Although huge companies such as ABB, Wärtsilä and Valmet had played important roles in global industrial production, but their sustainability strategies have not been systematically compared. It is still unclear how these companies differ in their sustainability approaches. Still there are also some unanswered questions regarding how the companies have integrated sustainability into their business operations and what are the benchmarks for comparing their performance to each other. Thus Finland is interesting for this research because a combination of strong regulatory controls on environment and sophisticated technologies along with demanding stakeholder expectations about sustainability prevails.

To fill these voids, this paper conducts a comparative case study on sustainability practices in three large, Finnish manufacturers: ABB, Wärtsilä, and Valmet. In detail, it discusses how organizations implemented real sustainability practices in its operational-, managerial, and reporting-activities. In that sense, this thesis is trying to provide a greater insight into organizational factors enabling or preventing a transition toward sustainability in a developed economy. The comparative design facilitates the identification of actual differences and its underlying causes and also guarantees detailed investigation in each case company.

This paper explains which organizational factors enabling or preventing the sustainability transition of developed economies by looking into what kind of sustainable practices organizations had implemented into operational, managerial and reporting activities. It also explains the main causes which enable or prevent sustainability transitions of organizations due to the comparative research design in this thesis. Each of these case companies is examined thoroughly and explored to determine whether the case companies had truly implemented real sustainability practices and discharged their responsibilities in response to rigorous environmental regulation.

3 Theoretical Framework

3.1 Triple Bottom Line (TBL) Framework

According to Tiuncika & Bormane (2024), the idea of TBL concept was coined by Elkington. This framework measures beyond financial returns and addresses environmental, social and economic aspects. TBL principle says that sustainable entrepreneurship should simultaneously act in three different dimensions where performance of each dimension is higher than pure profit maximization. The TBL framework has been widely applied to entrepreneurial research due to the extensive benefits that sustainability-oriented entrepreneurship may potentially have in relation to sustainable development efforts (Nica et al., 2025).

As for the environment, the main issue is the planet. Therefore, the objective of a company in this area can be seen as not just promoting environmentally friendly behavior, but also not promoting externalities because of the production processes. An organization can reduce and reverse the negative environmental impacts and contribute to environmental sustainability with improvement in the efficiency of the production process reduction in materials waste and carbon footprint, development of clean technologies, optimization of the resource usage, replacement of non-renewable resources with renewable (Tiuncika & Bormane, 2024). In the manufacturing sector the reduction of the GHG (greenhouse gases) is critical, improving energy efficiency and the reduction of water and waste are publicly declared using global standards like GRI and CDP (Nica et al., 2025).

In the environmental dimension, the central focus is the planet; thus, beyond simply advocating for environmentally friendly behavior, the main goal is to address the negative externalities caused because of production. A company can reverse ecological degradation and benefit environmental sustainability through optimization of production process through material waste and carbon footprint reductions, clean technologies, rational and responsible use of resources and substituting natural resources with renewables (Tiuncika & Bormane, 2024).For manufacturing businesses, this implies reducing

greenhouse gas emissions which results in greater efficiency in energy and water consumption and improved waste handling often publicly reported against such frameworks as the Global Reporting Initiative (GRI) and Carbon Disclosure Project (CDP) (Nica et al., 2025).

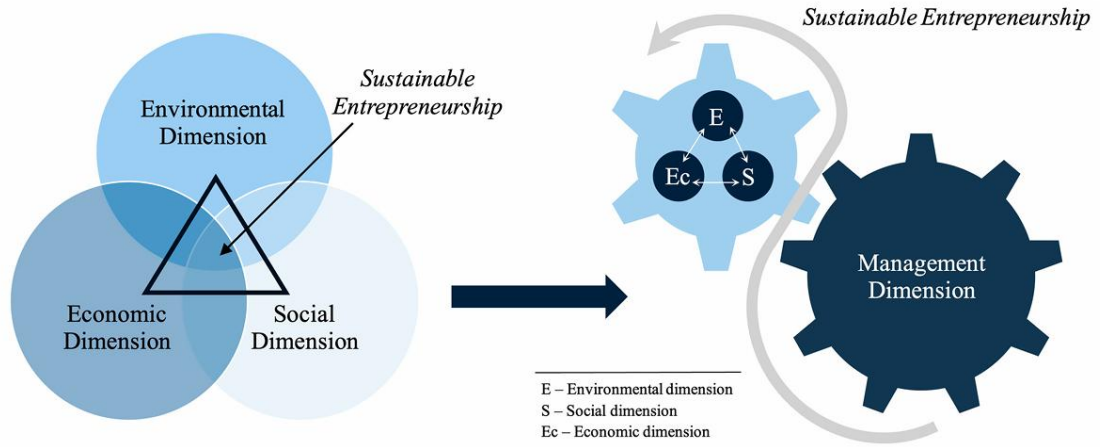

Figure 2. Integration of the Triple Bottom Line (TBL) and Management Dimensions (Tiuncika & Bormane, 2024**)**

According to Tiuncika & Bormane (2024), in the social dimension, the central element is people therefore, businesses are expected to uphold human rights and drive social change via different social programs and working together with stakeholders. Most of the changes can already be implemented within companies through cultural norms surrounding labor-inclusive workplaces, socially conscious treatment of employees, and in investment. Key indicators in this dimension include occupational health and safety performance, workforce diversity and inclusion metrics, employee engagement scores, fair labour practices throughout the supply chain & community engagement initiatives. For the industrial sector with global supply chains and international logistics, the social dimension also includes human rights as well as respect for freedom of association and elimination of forced or child labour.

In the economic dimension, the central object will largely remain to be profit. Thus, actions must align with sustainability principles while maintaining revenue streams

(Tiuncika & Bormane, 2024). These could be done by identifying market failures and promoting new markets as well as supplying operational products and corresponding services for their maintenance and also increasing end-user's consumption with decreasing effort. At policy making level, efficiency in the use of materials and energy, as well as a circular economy should be the main goals of companies for the resource loops to be closed (Tiuncika & Bormane, 2024). Economic sustainability in manufacturing is not just about being profitable and generating returns for shareholders, it means achieving long-term value creation through innovation, research and development investment and new business models that dissociate revenue gain from resource consumption. Meeting TBL values is imperative in sustainable entrepreneurship. Since the concern of environmental, social, and economic perspectives is now increasing globally so the "Triple Bottom Line" framework has also been given highly importance in this research paper (Nica et al., 2025).

3.2 Circular Economy (CE) Framework

The CE as foundational archetype can be traced back to work of the Ellen MacArthur Foundation that formalized both the concept and its principles to help guide a transition towards regeneration economic models. The Ellen MacArthur Foundation describes a CE as an industrial system that is restorative or regenerative by design and intention and what sets it apart from recycling in the conventional sense is its focus on innovation across systems and lifecycle thinking. A CE is based on a set of fundamental principles that drive the industrial system transformation: reduce, reuse, recycle and regenerate. (Setyadi et al., 2025).

According to Setyadi et al. (2025), the Circular Economy (CE) has grown to become a major element of modern sustainability debate in resource intensive sectors, e.g. manufacturers. The CE fundamentally seeks to shift the traditional linear economy narrative by promoting a restorative and regenerative approach to consumption and production. Instead of seeking efficiency via high-speed and -volume flow of materials in the linear

economy, the CE promotes systemic stewardship over resources with an overall goal to decouple economic growth from environmental degradation.

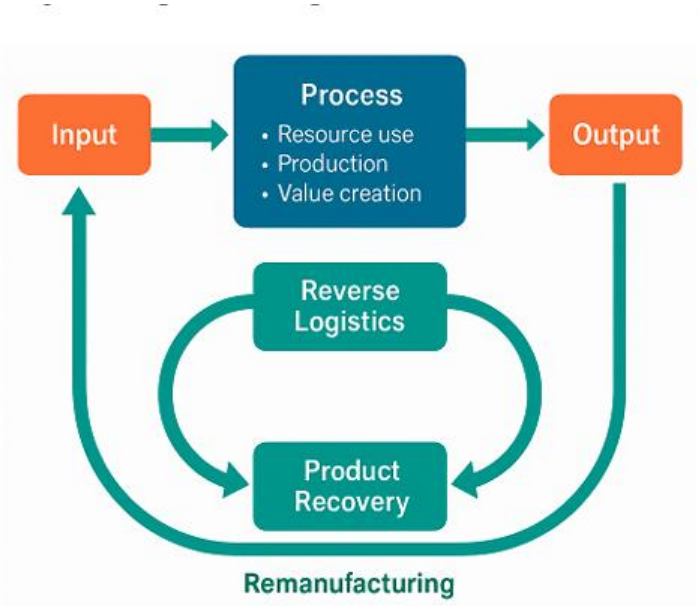

Figure 3. Circular Feedback Loop Mechanism for Sustainable Operations (Setyadi et al., 2025**)**

In manufacturing, these principles are operationalized through two dominant system ways that is closed loop system and open loop system. Closed loop systems is the system in which waste materials are reabsorbed into the production cycle as new inputs, so that there is no such thing as waste. This model requires technical innovations for sorting, disassembly and remanufacturing, as well as product designs that enable modularity and material recovery.

The closed-loop systems work collaboratively with various industries whereby; waste from a process is utilized as input for another process which has birthed the industrial symbiosis networks (Setyadi et al., 2025).Both approaches need system-up changes in product design, business models and cross-organization collaboration. Purushothaman et al. (2025) carried out a systematic literature review on the theories, techniques, and

strategies of sustainable circular economy in several manufacturing sectors. Using the PRISMA framework to review 124 studies, their article outlines the core theories, components, technologies and strategies that facilitate circular economy actions and create sustainable enterprises. Transitioning circular economy strategies to enable sustainable practices driven by emerging technologies such as Artificial Intelligence (AI), blockchain, and Internet of Things (IoT) for a circular economy has been the focus in this thesis (Purushothaman et al., 2025). These technologies enable improved traceability of materials, optimised reverse logistics, predictive maintenance that increases the life cycles of a product, and data-driven design for circularity. Resource availability, manpower, financial support and government policies all required for the successful implementation of circular economy practices (Purushothaman et al., 2025), were further identified in this regard. The Circular Economy framework is highly relevant to this thesis because all three case companies ABB, Wärtsilä, and Valmet have integrated circular principles into their sustainability strategies, although through different approaches. CE provides a structured lens to analyze how these companies manage resource efficiency, waste reduction, product lifecycle design and material circularity in their industrial production. By applying the CE framework, this thesis can systematically compare the circular economy practices across the three companies, identify best practices, and evaluate the extent to which each company has moved beyond linear production models toward regenerative systems.

3.3 Lean-Green Manufacturing Framework

The integration of lean and green manufacturing paradigms has emerged as a significant area of research and practice in sustainable operations management. The relationships between lean and green approaches in terms of their mutual influence in achieving target performance have been investigated in several studies, with most identifying a supportive relationship between the two paradigms, and only few negative effects have been identified (Domingo & Aguado, 2015).According to lean-green manufacturing

framework the combination of lean principles which centralizes on waste reduction, continuous improvement and value creation complemented by green principles are focused on environmental sustainability resource efficiency and pollution prevention provides synergistic benefits for organisations (Domingo & Aguado, 2015).

Lean manufacturing can increase the environmental performance of an organization since it focuses on eliminating all types of waste, such as overproduction, waiting time in queues and transportation, inappropriate processing based on customer rules, unnecessary stock levels or inventory for materials needed to manufacture a product, unnecessary movement within a workstation and defects. Each of these wastes contributes directly or indirectly to environmental impact that is waste in production consumes more materials and energy than needed, defects create scrap and rework, and transport creates emissions. Green manufacturing expands this scope to also include overall environmental effects, for instance emissions, resource depletion, and ecosystem degradation (Verrier et al., 2016). Several models have been proposed by the researchers to understand how lean and green practices can be integrated. Verrier et al. (2016) proposed the "lean and greenhouse" framework and a maturity deployment model that helps organisations assess their level of lean and green integration.

Their research shows that when companies implement lean and green practices together at the same time rather than in isolation, there can be simultaneous improvements in operational efficiency and environmental performance (Verrier et al., 2016). Domingo and Aguado (2015) introduced Overall Environmental Equipment Effectiveness (OEEE). The OEEE can be used to calculate and examine the performance of a lean and green manufacturing system.

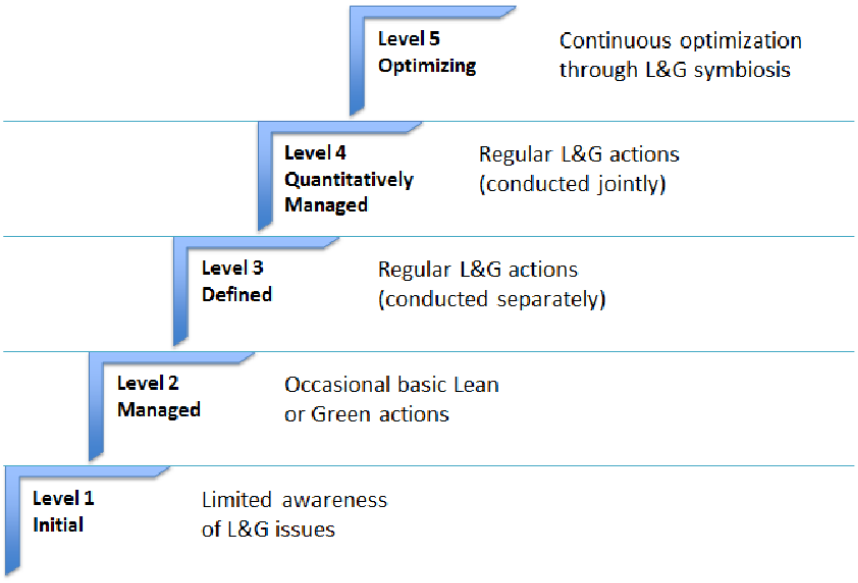

Figure 4.The Lean and Green Maturity Model (Verrier et al., 2016**)**

The integration of environmental principles with lean prospective is very relevant to the current thesis as sustainable manufacturing practices were central across all case companies chosen for this paper. The lean-green model is highly suitable to the assessment of such companies as ABB, Wartsila and Valmet, where the manufacturing function simultaneously addresses efficiency and environmental factors in its operations. Since Lean and green management approach are complementary to each other, for companies like those mentioned, operational and environmental performance is something that can be aimed for and enhanced rather than sacrificed.

3.4 Environmental, Social and Governance (ESG) Framework

The Environmental, Social and Governance (ESG) framework has emerged as the global standard for assessing corporate sustainability performance and responsible business

practices. While conventional frameworks only examine environmental features of the society, ESG offers a wider understanding to look into how businesses are applying efforts in tackling risk and creating opportunities in three interconnected areas, business-related impacts on the environment and on people (environmental), human capital management in a globalized world (social), and ethics, transparency, accountability and trust governance (Deirmentzoglou et al., 2026).

For manufacturing companies, this includes both direct operational impacts from production facilities and indirect value chain impacts (including supplier environmental performance). The environmental aspect focuses on the organizational effect of natural systems which includes carbon emissions, climate change prevention, resource depletion, waste management, water usage, biodiversity conservation and pollution avoidance (Deirmentzoglou et al., 2026)

The social aspect includes relationships with stakeholders, such as workplace culture, health and safety from work-related hazards, diversity and inclusion of workforce, human rights agenda through the engagement with communities and product safety (Deirmentzoglou et al., 2026).

As for companies with global supply chains, this includes respect for freedom of association and the elimination of forced or child labour in all tiers. This pillar of governance includes leadership structures, board composition and independence, executive compensation, shareholder rights, business ethics, transparency and anti-corruption measures.(Deirmentzoglou et al., 2026).The origins of ESG lies in the corporate social responsibility movements of the 1950s-1970s, however ESG as we know it today became normative through a series of key institutional milestones. It has since transformed from a voluntary measure at the corporate level to a structural barrier influencing global competitiveness, resilience and legitimacy (Deirmentzoglou et al., 2026). The rise of ESG as the leading framework stems from the recognition that sustainability risks affect long-term financial performance. Investors are using ESG ratings in capital allocation decisions

and large institutional investors are mandating portfolio companies to disclose ESG information.

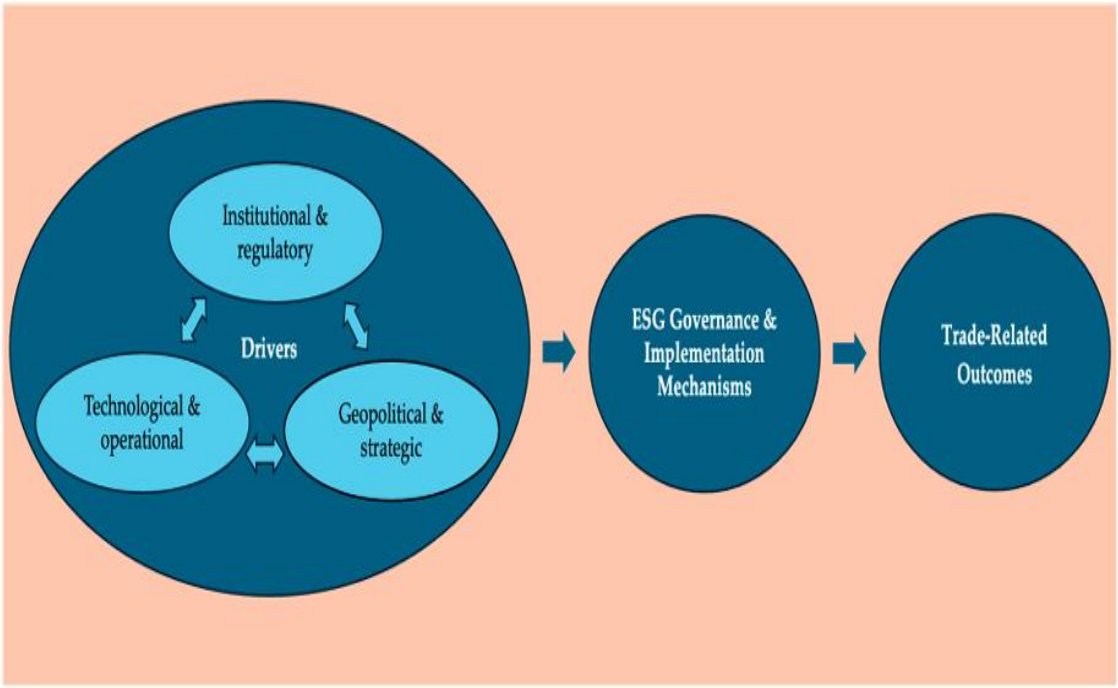

Figure 5. Integrative ESG–Trade Framework (Deirmentzoglou et al., 2026).

As illustrated in Figure 5, the ESG operates through three interdependent dimensions. Firstly, institutional and regulatory drivers which shape compliance and standardization across jurisdictions. Secondly, technological and operational drivers which enable digital traceability, monitoring and performance and thirdly geopolitical and strategic drivers that link ESG to energy security and resources.

Consequently, the ESG framework is highly relevant for this thesis, as it enables a systematic study of the sustainability performance of ABB, Wartsila and Valmet. Both companies have extensive disclosures of ESG aspects, their disclosures are largely guided by international guidelines such as GRI, and they are undergoing ESG rating evaluation

processes. In this systematic and comprehensive manner, the framework makes it possible to make comparative analyses along environmental, social and governance issues.

3.5 Conceptual Framework of the Study

This thesis uses a concept framework comprised of four lenses of sustainability TBL, CE, Lean Green manufacturing and ESG. This thesis is centered on the application of this integrated concept framework to systemically analyze and compare the sustainability practice of three major industrial manufacturing companies ABB, Wartsila and Valmet. The TBL framework has been used to define sustainability in terms of the environment e.g. Emission, energy use, waste then social e.g. Safety, diversity, well-being and economic e.g. financial return, customer impact factors. This thesis applies CE as another framework of analysis focusing on the loops, reduction and design aspect of the circularity of materials. Lean Green manufacturing is the lens of study for the interrelationship of economic (operational efficiency) and the environmental like as efficiency and waste. ESG aspect has been included to add the layer of governance in the analysis, such as management accountability, supply chain management, and transparency. The four-dimensional framework would be applied to analyze sustainability reports of the three case companies from 2022 to 2024, followed by case companies analysis the common aspects e.g. High level emission reductions, safety records or high level incentive programs for managers on ESG and differences e.g. different circular economy strategies or level of integration with green finance and the diversity in social reporting detail) and how these relate to TBL, CE and ESG framework, therefore to answer the three research questions and providing insights both conceptually and practically.

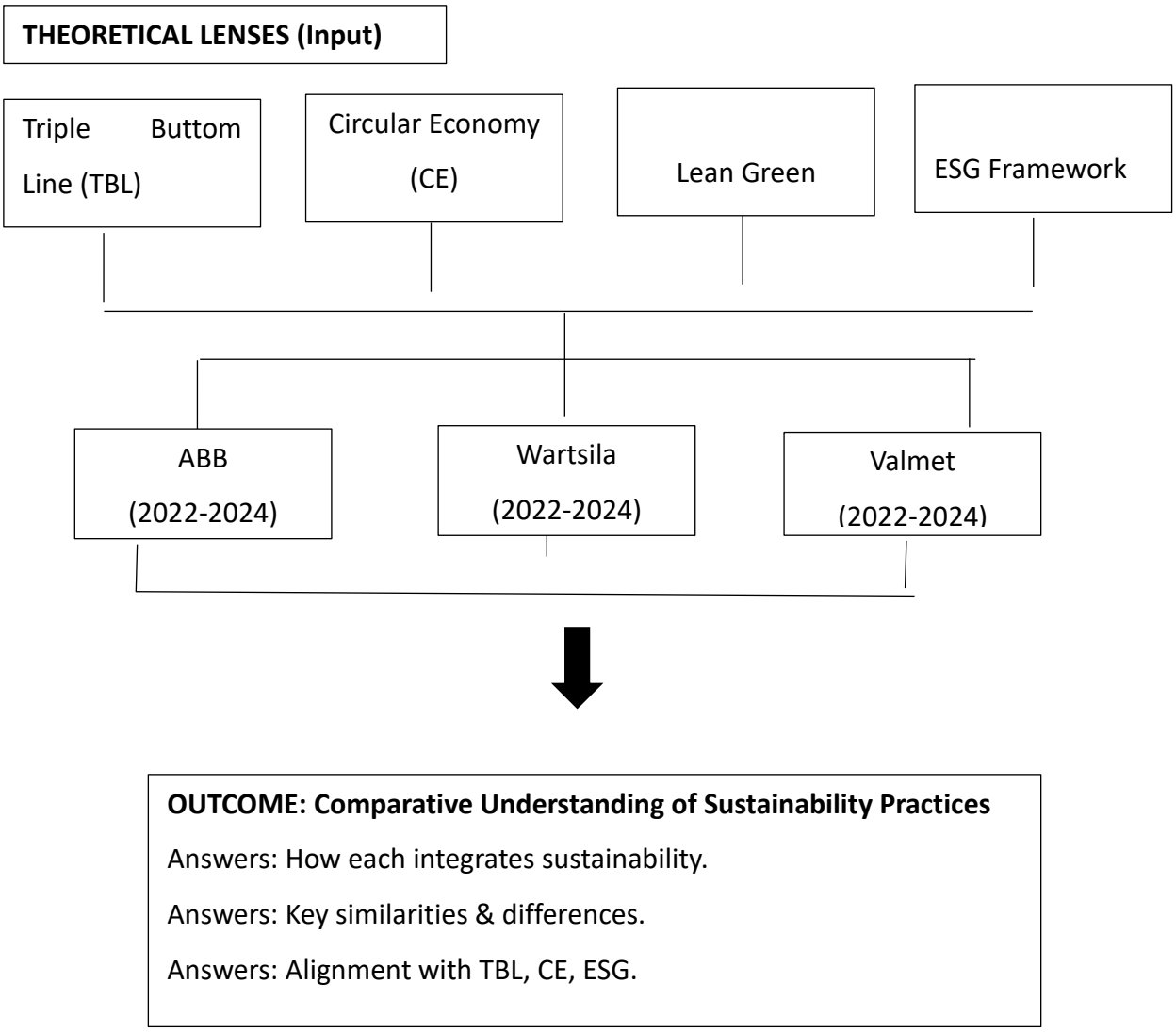

Figure 6. Conceptual Framework

4 Research Methodology

This chapter outlines the methodological approach adopted to investigate sustainability practices in selected manufacturing companies. It provides a detailed account of the research approach and design, the nature of the study, data sources, data collection procedures, and analytical techniques employed. The chapter also addresses issues of reliability, validity, and ethical considerations to ensure credibility of the research findings.

4.1 Research Approach and Design

According to Creswell & Poth (2018), Qualitative research is defined as a research approach that helps researchers to understand and interpret the social phenomena through exploring the meanings, experiences of participants and perspectives of institution entirely in their natural order. Qualitative research is distinct from quantitative research that solely focuses on statistics, hypothesis testing and qualitative inquires. Today, sustainability practices are well emphasized in manufacturing sector. Sustainability practices implanted its root in organizational culture, its strategic priorities, regulatory environments and stakeholder expectations all over the world. In manufacturing sector sustainability practices dimensions are complex. So qualitative approach enables a deep examination of how sustainability is conceptualized, implemented, and communicated within companies. As well as how managers and organizations interpret their environmental and social responsibilities. Companies' sustainability reports are vague with different statistics and data. The core strength of qualitative research is to figure out how the companies frame, prioritize, and communicate their sustainability data.

Comparative research helps with a structured exploration of the similarities and differences among two or more cases to advance understanding and knowledge at a theoretical level (Bryman, 2016). Comparative research can go beyond describing individual cases and make visible the patterns, variations and contextual factors shaping an organization or phenomenon. In this thesis, a systematic comparison is made among three selected manufacturing organizations (ABB, Wartsila and Valmet) to highlight similarities

and differences between these three firms in terms of sustainability strategies, sustainability reporting, and integration into operations.

The qualitative comparative design has been suitable for the purpose of this thesis because sustainability implementation differs significantly from one firm to another depending on certain aspects like size of the company, form of ownership, exposure to market, type of sub-sector they belong to, etc. It allows to increase analytical quality by comparing more than one case study to draw firm specific as well as broad industry conclusions. As indicated by Yin (2018), research designs that are comparative and based on case studies tend to make the conclusions stronger; it adds replication logic and cross-case synthesis which leads to a much more robust theoretical understanding.

4.2 Nature of the Study

This thesis is qualitative in nature. It is also exploratory because it aims to build more insight into sustainability practice structures, implementations and reporting mechanisms. Qualitative exploratory studies are appropriate when investigating complicated organizations phenomenon (Creswell & Poth, 2018). This thesis explores on the content of the sustainability practices companies disclose. It is comparative as it provides a systematic comparison between multiple manufacturing companies such as ABB, Wartsila and Valmet. This thesis intends to identify similarities and differences in sustainability strategies, reporting practices, and operational integration. Comparative qualitative research allows context to a subject while also enables the analytical generalization across different cases (Bryman, 2016).

Furthermore, the research analyses the sustainability reports over a three-year period from 2022 to 2024. This time frame facilitates the researcher to analyze on how sustainability practices evolve and perform over time. The nature of sustainability practices is complex because it consists of strategic decision-making, extensive stakeholder engagement and profound long-term organizational transformation. So, it is necessary to study this detailly, so comparative qualitative approach is best option for this thesis.

4.3 Sources of Data and Company Selection

4.3.1 Company Selection Criteria

The case companies, i.e. ABB, Wärtsilä and Valmet were chosen by purposive sampling where companies are selected based on the traits that matches the objectives of research. The details of selection traits for this research are as follows:

Industry sector: All three companies are in the industrial manufacturing segment, most notably within energy, power generation, marine & process technologies. Since they have common sector that permits this thesis to conduct meaningful comparisons of sustainability practices as well as allowing for the comparisons of their operational differences.

Geographic origin: These three case companies are based in Northern Europe Headquarter of ABB in Switzerland, Wärtsilä, and Valmet have their headquarters in Finland. Although they have many factories in various parts of the world, they share the same degree of regulatory and cultural consensus around sustainability expectations. Their geographic proximity also means that they fall under the same European Union sustainability regulations and directives, including the EU's Corporate Sustainability Reporting Directive (CSRD) and Taxonomy Regulation.

Public reporting: All three case companies published their detailed annual and sustainability reports in English following the international reporting frameworks (GRI, SASB, TCFD). Since the data are publicly accessible, this thesis to have a systematic comparison of sustainability practices.

Sustainability leadership: Each company has been identified as a leader in sustainable practices within its respective subsector. ABB has been on the Dow Jones Sustainability

Index several years in a row, Wärtsilä scored A- leadership ratings in CDP Climate rankings, and Valmet's EcoVadis score has increased year-upon-year, as well as being continuously certified by ISO 14001 in major operations.

Timeframe coverage: All three companies have published sustainability or integrated reports thematically covering the full study period (2022–2024) of this thesis which allows for consistent longitudinal analysis. It is important for monitoring the changes of sustainability strategies and performance over years.

4.3.2 Data Sources

The sustainability reports, annual reports and integrated reports from ABB, Wartsila and Valmet for the years 2022-2024 were used as primary data for this thesis. These were downloaded from their websites and analyzed. Detailed list of the analyzed documents includes sustainability reports that are used to cover the environmental, social, and governance performance, the standard practice for such reports is that they are based on GRI standards. Annual reports that provide the financial performance, strategies of the company, and in most cases, sustainability information are provided within the report. Integrated reports that can be concluded as a combination of sustainability information and financial information in a single report and they are structured according to the International Integrated Reporting framework. The thesis includes also other documents like climate action plans, tax transparency reports, human right statements, green finance reports, etc. when it is applicable. All reports are extracted from the company's own website.

4.4 Data Collection

Data were retrieved from the official websites of ABB, Wärtsilä and Valmet. Sustainability report, annual report and integrated report for the period of 2022, 2023 and 2024 were downloaded for each company. All these reports were stored in a computer folder

categorized with company names and respective years. The reports were examined one by one in order to select important environmental, social and governance information.

4.5 Data Analysis

This section describes the step-by-step process that is used to analyze various reports. The analysis was conducted manually following the systematic process which is described below.

Step 1- Reading and familiarization: All sustainability reports, annual reports, and integrated reports from ABB, Wärtsilä, and Valmet from the years 2022–2024 were studied carefully. The key sections which are related to environmental performance, social performance, governance, and circular economy were emphasized for further analysis

Step 2- Data extraction based on theoretical frameworks: By using the four selected frameworks Triple Bottom Line, Circular Economy, Lean-Green, and ESG as a guiding framework the relevant data were extracted from each report. This included:

1. Quantitative data including percentage decrease in emission, amount of renewable energy used, waste percentages, safety figures, and diversity percentages, etc.
2. Qualitative description such as circular economy practices described by companies, description of engagement with suppliers, descriptions of incentives for executives.

Step 3- Organizing data into a comparison table: The extracted data were manually entered in Excel. Each company data was entered and organized on their own sheet. The collective data of companies allowed for direct side-by-side comparison of all case companies.

Step 4- Identifying patterns : The completed table was analyzed to identify:

1. Convergent patterns (practices or outcomes common to all three companies)
2. Divergent patterns (practices or outcomes where companies differed)

Step 5: Thematic grouping: Similar types of information were grouped into themes. For example:

1. Emissions, energy, and waste were grouped under "Environmental performance"
2. Safety and diversity were grouped under "Social performance"
3. Executive incentives and supplier engagement were grouped under "Governance"
4. Circular economy practices were grouped under "CE"

Step 6: Writing findings: The findings are presented in Chapter 5. The chapter begins by describing each company's sustainability practices individually, followed by a cross-comparison of convergent and divergent patterns, and concludes with the thematic findings.

4.5.1 Content analysis

Content analysis in this thesis was conducted simply by counting and comparing quantitative indicators reported by the three companies. For example:

1. Emission reduction percentages were compared across ABB, Wärtsilä, and Valmet.
2. Renewable electricity shares were compared.
3. Lost Time Injury Frequency Rates (LTIFR) were compared.
4. Percentage of women in management was compared

When companies used different baseline years or different metrics, direct quantitative comparison was not possible. In such cases, qualitative comparison was used instead

(e.g., describing the direction of progress rather than exact numbers). No statistical tests or complex coding schemes were used. The analysis was purely descriptive and comparative.

4.6 Reliability, Validity, and Ethical Considerations

4.6.1 Reliability

For ensuring reliability, this thesis follows a clear step-by-step procedure which is outlined in Section 4.5 and Section 4.5.1. Data were collected from published reports by ABB, Wärtsilä and Valmet from 2022-2024 and were categorized under four different theories (TBL, CE, Lean-Green, ESG) into comparison tables.

4.6.2 Validity

Several published reports were included for each company such as sustainability reports, annual reports, and integrated reports for the enhancement of the validity of the thesis. Multiple reports from each company increases the validity by minimizing the reliance only from a particular report.

4.6.3 Ethical Considerations

All documents used in this thesis were downloaded from public websites of ABB, Wärtsilä, and Valmet. No human participants, interviews, or confidential data were involved. The three companies are represented fairly and accurately based on what they have publicly reported. The thesis was conducted following the ethical guidelines of the University of Vaasa, including academic integrity, honesty in reporting, and proper citation of all sources

5 Results and Findings

This chapter elaborates about the results and findings obtained through various reports publicly published by three case companies. Table 1 presents an overview of the sustainability reports analyzed by each company during the study period. Indeed, all three companies prepare their reports in line with international frameworks like the Global Reporting Initiative (GRI) and the Sustainability Accounting Standards Board (SASB), rendering some level of interaction between diversified disclosure. All companies have been reporting according to the EU's CSRD (Corporate Sustainability Reporting Directive) as of 2024.

TABLE 1. Sustainability Reports Analysed by Company and Year

Company	**2022**	**2023**	**2024**
Valmet	Annual Report, GRI Supplement		Annual Report, Sustainability Report, Green Finance Report
ABB	Integrated Report, Sustainability Report		
Wärtsilä	Annual Report, Sustainability Report		

General Note on Data Attribution

As per the reports listed in Table 1, all tables, figures and data presented further from here are based on official corporate reporting suites of ABB, Wärtsilä and Valmet for the period 2022–2024. Also, to ensure the readability and visual clarity of our comparative analysis, multiple data points have been aggregated into a single citation. All data in the following sections, unless specified by a unique citation or footnote, should be understood as:

1. Extracted from the reports listed above.
2. Compiled and rearranged by the author for comparative purposes; and
3. Accuracy has been cross-referenced across multiple annual and sustainability disclosures.

5.1 Sustainability Principles in Practice

The four-sustainability theoretical frameworks TBL, CE, Lean-Green and ESG, have been adopted to interpret the sustainable value of industrial production.

TABLE 2. Sustainable Practices data (Source: Multiple documents listed in Table 1)

No.	Framework Dimension	ABB	Wärtsilä	Valmet
Environmental (TBL)				
1	Emissions Reduction (Scope 1&2)	78% reduction (since 2019)	50% reduction (since 2021 baseline)	49% reduction (since 2019)
2	Renewable Electricity	95% (2024)	68% (2024)	68% (2024)
3	Waste to Landfill	5.8% of total waste	Undisclosed	5.8% of total waste
4	Recycling/Recovery Rate	82–86%	Undisclosed	77%
Social (TBL)				
1	Safety (LTIFR)	0.15 (2024)	1.59	1.6
2	Women in Management	21.3% senior management (2024)	22% executive positions	22% senior managers
3	Women in STEM	Undisclosed	Undisclosed	12.4% (exceeds 12% target)
4	Gender Pay Gap	Undisclosed	Undisclosed	-0.23% (favouring women)
Economic (TBL)				
1	Customer Impact	204 Mt CO_2e avoided emissions (cumulative since 2022)	Zero-carbon fuel development	EUR 250 million green finance
2	Financial Performance	$32.9B revenue (2024)	€6.4B net sales (2024)	€5.4B net sales (2024)

Circular Economy (CE)				
1	Explicit CE Strategy	✓ 2030 target: 80% portfolio circularity	Implicit through resource efficiency	✓ Beyond Circularity R&D programme
2	Material/Resource Reduction	Undisclosed	45% material reduction (since 2018)	Steel recycled content: 77% (foundries)
3	CE Programme Scale	Undisclosed	Undisclosed	280+ partners, 35 projects, EUR 40M investment
Governance (ESG)				
1	Executive Incentives	2 of 3 annual goals linked to sustainability	Sustainability linked to long-term incentives	25% weight in Performance Share Plan
2	Supplier Engagement	68% of high-risk suppliers covered	Contractor EHS programme	94% suppliers signed Code of Conduct
3	Reporting Frameworks	GRI, SASB, SBTi	GRI, Eurostat-aligned	GRI, CSRD, EU Taxonomy

These companies follow the EU and Finnish policies, as well as professional and societal expectation for sustainment. ABB demonstrates the most explicit integration of circular economy through portfolio-level assessment. Wärtsilä exemplifies circular outcomes achieved through operational efficiency. Valmet represents an ecosystem-based collaborative innovation model through its Beyond Circularity programme. ABB engages in circular economy by assessing its portfolio at a transparent more transparent level. Wärtsilä is an example of circular results realized through operational efficiency. Beyond its circularity programme, Valmet forms an ecosystem-based collaborative innovation model.

5.2 Cross-Comparison Analysis

For a clear understanding of the sustainability practices the convergent and divergent patterns of the three companies are given below.

5.2.1 Convergent Patterns

1. **Regulatory Anchoring**: All three companies follow EU's CSDR and Taxonomy regulations as their regulatory foundation. In case of ABB's its sustainability targets were validated by SBTi in 2024. Sustainability Statement (2024) by Valmet has aligned with CSRD. from 2024 Wärtsilä's had also aligned its sustainability report is as also as per CSRD.

2. **Executive Accountability**: Each company has linked sustainability metrics to executive compensation. ESG criteria covers 25% within Valmet's Performance Share Plan. Among ABB's three corporate goals two goals are tied to sustainability outcomes. Wärtsilä reports its sustainability integration into long term incentive structures. Such convergence is the sign of mature governance integration in three companies.

3. **Safety Excellence:** All three companies perform strongly in occupational safety. ABB's industry-leading LTIFR of 0.15. Wärtsilä and Valmet has been conducting good safety programmes and is continuously improving.

4. **Scope 3 Recognition:** Each company acknowledges value chain emissions as the next frontier. Valmet leads with 21% Scope 3 reduction since 2022 and SBTi-approved targets. ABB reports 8% Scope 3 reduction since 2022. Wärtsilä has expanded its Scope 3 reporting scope in 2024 and committed to a 25% reduction of direct suppliers' GHG emissions by 2030.

5.2.2 Divergent Patterns

1. **Circular Economy Approach:** ABB adopts a clear and quantifiable portfolio strategy with a target to achieve 80% circularity by 2030. Wärtsilä delivers a strong 45% materials reduction, although without explicit circularity labeling of their strategy and portfolio. Valmet pursues an ecosystem approach through their initiative Beyond Circularity, engaging 280 partners with 35 projects and an investment of EUR 40 million. This divergence implies there is more than one equally appropriate path to circularity.

2. **Green Finance Integration:** Only Valmet explicitly highlights its integration of green finance with a published Green Finance Framework, issuing EUR 250 million in green bonds and loans. In their 2022-2024 reports neither ABB nor Wärtsilä report comparable instruments. This could be regarded as the best practice to adopt.

3. **Diversity Performance Measurement:** Although all reports improved gender diversity, they report it in different ways. Valmet's detailed social indicators that is 12.4% of STEM diversity and -0.23% gender pay gap is another best practice.

5.3 Findings

Thematic analysis of the sustainability reports produced six central themes. Each theme was identified through recurrent patterns across companies and validated through secondary data where possible.

TABLE 3. Cross-Company Comparison of Key Sustainability Themes (Source: Multiple documents listed in Table 1)

SN	Theme	ABB	Wärtsilä	Valmet
1	Regulatory Anchors	Strong emphasis	Present/developing	Strong emphasis

2	Executive Accountability	Strong emphasis	Present/developing	Strong emphasis
3	Circular Economy Integration	Strong emphasis (explicit)	Present/developing (implicit)	Strong emphasis (ecosystem)
4	Safety Excellence	Strong emphasis	Strong emphasis	Strong emphasis
5	Scope 3 Management	Present/developing	Present/developing	Strong emphasis
6	Green Finance	Undisclosed	Undisclosed	Strong emphasis

5.3.1 Regulatory Anchors

Regulatory frameworks were clear enablers in all three case companies. ABB's scope 1, 2 and 3 targets for 2030 & 2050 were approved by the SBTi in 2024 under the Net-Zero Standard. Valmet's reporting on the CSRD in 2024 which is ahead of regulation. Wärtsilä's transferring to a CSRD-based reporting framework from 2024 onwards. These clearly indicate institutional responsiveness. The EU Circular Economy Action Plan (2020), the EU Taxonomy Regulation and the CSRD create as in the words of an ABB report a predictable policy environment which drives investment over the long-term.

5.3.2 Executive Accountability

Sustainability was integrated into the structures of governance across all three companies. Valmet's link into the Performance Share Plan is 25%, which stands out as the clearest example. ABB integrates two out of its three annual corporate goals into the reporting on its performance and Wärtsilä reports an integration of its sustainability aims into its long-term incentive plans. It is clearly noticed that sustainability was covered at Board level. Each company provided information on the regular reports of ESG risk exposures. This governance maturity shows that these companies treat sustainability as strategic rather than compliance driven.

5.3.3 Circular Economy Integration

Three main types of circular economy pathways have been identified:

1. ABB:The target for ABB to achieve in 2030, that 80% of their product portfolio must show circularity, describes a quantified, systematic circularity approach. The EcoSolutions label, for instance, validates these circular economy claims from a third party.

2. Wärtsilä: Wärtsilä does not directly frame their actions as circular economy but manages to achieve circular benefits. For example, they reduced their usage of materials by 45% since 2018. The example demonstrates that there are "lean gains in operational efficiency that deliver circular benefits". It indicates circularity results can be achieved also without explicit circular economy programs.

3. Valmet: This corresponds to The Beyond Circularity program which has 280+ partners, 35 projects and an investment of EUR 40 million. In 2024, the program gained excellent speed and momentum, with the first launches emerging from the program. This recognizes that circular transitions require cross-company efforts beyond a firm’s capabilities.

5.3.4 Safety Excellence

Safety is also one of the common strengths. ABB is one of the top companies worldwide regarding the LTIFR of 0.15. Wärtsilä and Valmet have had good safety performance with clear upward trend. The culture of zero-harm is expressly written in company values for all of the companies.

5.3.5 Scope 3 Management

Scope 3 emissions are the emerging frontier. Valmet has a leadership position, with approved Science Based Targets of reduction of 25% in its value chain (Scope 3) by 2030 from a 2022 baseline. ABB have reported 8% Scope 3 reduction since 2022 and are targeting 25% in 2030 and 90% in 2050. Wärtsilä have set a 25% reduction in their direct suppliers GHG emissions by 2030. Supplier engagement programs are well developed in all three. ABB have a Sustainable Supply Base Management scheme that now covers 68% of high-risk suppliers. Valmet have reported that 94% of suppliers with their spending have signed up to its Supplier Code of Conduct. Wärtsilä have reported that they are developing EHS programs for contractors. All these approaches tackle scope 3 category 1 that is purchased goods and services.

5.3.6 Green Finance

Among the three, Valmet uniquely showcases green finance integration. The Green Finance Report 2024 contains data relating to the allocation and impact of proceeds from Green Debt transactions undertaken under the Green Finance Framework. Neither ABB nor Wärtsilä reported on similar instruments during 2022–2024 disclosures and this appears to be a emerging rather than well-established industry practice.

5.4 Empirical Findings

The empirical analysis of ABB, Wärtsilä, and Valmet yields five major findings that answer the research questions:

Finding 1: Good environmental performance in all companies.

ABB (78% Scope 1 & 2 reductions since 2019), Wärtsilä (50% reductions by the end of 2024 from a 2021 baseline) and Valmet (49% Scope 1 & 2 reductions since 2019) have already made strong commitments in their reduction targets. The companies had also reported having very high levels of renewable electricity in their energy mix, ranging from 68%-95%. Similarly, all three companies are also performing strongly in the waste aspect and show significant decreases. This empirically confirms that rapid decarbonization is technically and operationally achievable in heavy industry manufacturing companies.

Finding 2: Several possible ways for the integration into circular economy.

The three companies show three distinct possibilities in which they have embraced circular economy. ABB have done by its portfolio assessment, Wärtsilä by improved operational performance and Valmet by ecosystem innovation. This shows that there are different ways by which circular economy can fit within a strategic position.

Finding 3: Systemic attention to social sustainability.

Although prior literature argued that the social component lags the environmental side of things in companies. But this thesis reveals the companies' consistent efforts toward managing social sustainability. ABB's Safety performance of LTIFR 0.15 and diverse management composition by women in management 21-22% clearly indicates this. Plus, the specific social indicators like Valmet's STEM diversity are at 12.4% and gender pay gap at -0.23% should also be highlighted

Finding 4: Good governance guarantees credibility.

All three companies have proved the seriousness of their intentions by embedding sustainability in their corporate governance. Companies have been linking incentives of the top management to environmental indicators like Valmet Performance Share Plan has an environmentally weighted component of 25% of total compensation. And also, by pushing sustainability across its supply chain with 68%-94% coverage and through

reliable reporting (GRI, SASB, CSRD). Furthermore, ABB and Valmet were verified by SBTi. These initiatives provide them credibility and decrease their sustainability risk exposure.

Finding 5: Sustainability and economic performance are linked

The data achieved reinforce that sustainability investments bring improvements in the overall economic performance of a company rather than damage it. ABB's saved 204Mt of emissions, the repositioning of Wärtsilä's zero-carbon fuel strategic and the successful issue of €250 million in green finance bonds by Valmet indicate that sustainable is a good investment strategy.

5.5 Case Companies Performance Summary

Since 2019 ABB has lowered their emissions Scope 1 and 2 by 78% . This shows they are on track to reach their 2030 carbon neutrality goals. ABB's electricity usage by renewable sources was 95% by 2024, and only 5.8% of waste went to landfill and waste sent for recycling during the reporting period was 82-86%. The organization has also published Scope 3 emissions reduction figures with an 8 percent reduction by 2022 and a goal to reach 25 percent reduction by 2030. ABB's products' users have offsets 204 million tonnes of COe of downstream emissions through downstream avoided emissions since 2022. This proves the effectiveness of ABB's products in enabling downstream decarbonisation. Socially, it has achieved the industry-leading 0.15 lost time injury frequency rate and increasing the proportion of its women senior managers to 21.3 percent. Governance of ABB is advanced because two of the three annual corporate targets are tied to sustainability performance; a Sustainable Supply Base Management program covers 68% of high-risk suppliers. ABB's circular economy proposition is explicit and portfolio-focused, seeking to apply a circularity approach to 80% of its portfolio by 2030, covering 41% as assessed today. ABB recognizes that challenges remain: Scope 3 data accuracy, labor-intensive portfolio circularity assessments and workforce diversity.

Wärtsilä has achieve 50 percent decrease of their total greenhouse gas emissions in 2024 from a 2021 baseline, while their electricity from renewable sources is at 68 percent and their material input is at 45 percent less than in 2018. Energy savings is 34 gigawatt hours at the end of 2024 and has surpassed their target. Wärtsilä may not term their strategy explicitly a "circular economy," but their operation outputs are indeed impressive that is a decrease in hazardous waste of 51 percent from 2018. This was achieved from the design of their engine platforms so that they may be used for several kinds of fuel, including hydrogen and ammonia. In the social aspect, total recordable injury frequency rate is low and representation of women at executive level was 22 percent in 2023. All employees received training on the Code. At the governance level, the company is connecting their long-term incentives with their sustainability goals and from 2024, they produce sustainability reports under Corporate Sustainability Reporting Directive. Wärtsilä pledged to work with their direct suppliers to reduce the emissions by their supply base by 25 percent by 2030. Their greatest challenges are the complexity in Scope 3 measurement, to expedite transition towards renewable energy, and maintain progress on diversity.

Valmet has already achieved 49% reduction of its Scope 1 & 2 emissions since 2019 and 21% of Scope 3 since 2022 (targets approved by SBTi). In 2024 the share of renewable electricity is 68%, waste sent to landfill reduced 40% to 5.8% of the total waste. The company share of recycled steel and iron in Valmet foundries is 77%. Over 280 partners participate in green transition projects through Valmet's Beyond Circularity programme, where Valmet has invested EUR 40 million between 2022 and 2025. In social performance, women hold 22% of top management roles and 12.4% of all STEM roles (above the target of 12%) and the gender pay gap is negative 0.23% for women. Total recordable incident frequency is 3.2 in 2024. In governance, sustainability has a 25% weight in Performance Share Plan, A Green Finance Framework, supporting EUR 250 million worth green bonds/loans, has been issued. Valmet’s Supplier Code of Conduct has been signed

by 94% of the suppliers by spending. Valmet's sustainability statement conforms to CSRD and is subject to a limited assurance from external auditors. Challenges faced by Valmet include complexity of Scope 3 measurement, ongoing development of supplier capabilities and momentum of diversity initiatives.

6 Discussion

This chapter critically analyzes the findings of chapter 5 in relation with the theoretical frameworks provided in Chapter 3 that is Triple Bottom Line (TBL), Circular Economy (CE), Lean-Green Manufacturing, and Environmental Social Governance (ESG).The goal is to explain the empirical findings in a systematical way, show compatibility with theories and derive implications for practice in industrial management.

6.1 Application of Triple Bottom Line (TBL) Framework

The application of finding with respect to Triple Bottom Line is as follows.

6.1.1 Environmental Dimension

The findings below verify substantial environmental progress of the three companies: Firstly, all three companies have hugely improved their ecological performance. Since 2019, ABB reduced its Scope 1 and 2 emissions by 78%. From 2018, Wärtsilä has decreased material consumption by 45% along with hazardous waste by 51%. Valmet achieved a 49% reduction in emissions with its targets approved by the Science Based Targets initiative (SBTi). These results clearly demonstrate that rapid decarbonization is technically and operationally achievable along with heavy industrial manufacturing.

6.1.2 Social Dimension

All companies demonstrate strong occupational safety performances. Social sustainability has improved steadily in all three companies. Safety performance remained strong. ABB achieved an industry leading Lost Time Injury Frequency Rate (LTIFR) of 0.15. Gender diversity in management has reached 21–22% across the companies. Val-met shows particularly strong performance, with almost equal pay between men and women by –0.23% pay gap and by exceeding its target for diversity in STEM roles by 12.4%. These results confirm that companies can include social sustainability in their governance systems, workforce development and in their compensation structures.

6.1.3 Economic Dimension

The findings strongly support the TBL proposition that sustainability reinforces, rather than undermines, economic performances. These findings confirm that sustainability reinforces rather than compromises economic performance. ABB's 204 million tonnes of cumulative avoided emissions, Wärtsilä's strategic positioning through zero-carbon fuel development, and Valmet's EUR 250 million green finance issuance demonstrate that environmental and social investments enhance long-term competitiveness.

6.2 Application of Circular Economy (CE) Framework

The three companies show three different, but all valid ways, towards circularity. The CE assessment on 41% of the ABB portfolio with target on 80% by 2024 and EcoSolutions labelling shows a strategic portfolio-based approach and advanced CE implementation with verified transparency by third party. Material reduction (45%), hazardous waste reduction (51%) shows that there can be strong circular benefits by operational excellence even without the usage of CE terminology. Valmet with their Beyond Circularity programme (over 280 partners and 35 ecosystem projects) shows a collaboration-based innovation strategy towards CE and invests €40 million.

6.3 Application of Lean-Green Manufacturing Framework

The framework of Lean-Green claims that operational efficiency (lean) and environmental performance (green) mutually strengthen each other instead of confronting each other (Domingo & Aguado, 2015). Verrier, Rose and Caillaud (2016) found that companies can have combined improvement.

The combined effect was verified through the practices: 45% material decrease by Wärtsilä represent typical lean concept – reduction of waste, leading to the direct benefit to

the environment. 22% energy decrease by ABB and 7% by Valmet since 2019 represent that increasing efficiency is indeed decreasing emissions.

The results are consistent with the Extended Smart-Green-Resilient-Lean (SGRL) Framework, suggesting that combined implementation leads to higher performance. Strengths of each company are summarized as the ABB's strong on smart and green technologies by adopting smartness of automation and information technologies. Whereas, Wärtsilä strong in operational lean efficiency through material/waste reductions and Valmet's balanced on all dimensions of Smart-Green-Resilient-Lean through the well-structured implementation.

6.4 Application of the ESG Framework

The ESG framework brings governance on top of environmental and social performance. The environmental performance of all three companies is good through emission reduction, renewable energy sourcing and circular economy concepts. The social aspects of ABB's LTIFR (0.15), Wärtsilä contractor EHS programmes and Valmet's robust Social Responsibility Programme reflect methodical commitment to worker welfare. Governance is a strength: all three firms link executive remuneration to sustainability targets, the ESG component being 25 percent of the incentive payout in Valmet's performance share plan and two out of three corporate targets being sustainability-driven at ABB. All three have mature supplier management practices: 68 percent of ABB's high-risk suppliers have been engaged on ESG topics, 94 percent of suppliers by spend are signatories to Valmet's Code of Conduct and 98 percent have completed Wärtsilä Code of Conduct module. All three have certifications for ISO 14001, ISO 45001, and are reporting against GRI and SASB, with increasing coverage under CSRD. The Valmet green finance framework of 250 million euros is the best practice trend.

6.5 Cross-Case Synthesis

Common convergent trends across all three firms are high emissions reductions (ABB 78%, Valmet 49% and Wärtsilä 50%), high shares of renewable electricity (ABB 95%, others 68%), good safety performance and demonstrable progress on diversity (21-22% female management). They all agree on scope 3 as the key challenge, and on sustainability being tied to executive compensation. Key differentiating divergent trends show how each company's strategy plays out: ABB employs a conscious strategy for portfolio circularity, Wärtsilä delivers on circularity through a focus on lean operations instead of explicitly using the CE concept, while Valmet works on ecosystemic circularity through the "Beyond Circularity" agenda and is the clear leader on green finance and social granularity. This indicates that differences are not weaknesses, but context-sensitive interpretations of the challenge and opportunities sustainability offer. The unifying characteristic is that sustainability is not achieved at the expense of profitability.

6.6 Implications for Industrial Management

In terms of Strategy, there needs to be a systematical approach to integrating sustainability into the business strategy as opposed to peripheral operations. It needs to be part of the core business, whereby management are setting targets that are science based and assessed by SBTi, executive remuneration has been linked to ESG KPIs and "green finance" has been utilized to reduce capital costs. In Operational terms, there is no better solution to implement lean and green simultaneously as elimination of waste immediately leads to environmental gain. Material efficiency is a key KPI and sustainability principles are required in R&D and product development. Management systems such as ISO 14001 and ISO 45001 are the bare minimum. In Supply Chain, it requires formal supplier engagement programs with requirements and clear reporting, audits and training, science-based targets. Finally in Governance the boards need to take responsibility for

sustainability, the incentives need to be linked to ESG from board level right down to individual operational level, reporting needs to be transparent under GRI, SASB or CSRD and assurance by third parties should be obtained for significant indicators.

6.7 Challenges and Opportunities

Challenges: measuring Scope 3 still requires careful consideration of data quality issues. Portfolio circularity assessments are complex and resource intensive. Although diversity increases can be monitored, progress remains slow in comparison to goals. The green finance market is new and requires sound verification mechanisms. Opportunities, on the other hand: by working with suppliers, scope 3 issues can be managed as a whole. Technology (AI, IoT, digital twins) enables better use of the circular economy. Green financial instruments (green bonds, loans) can decrease cost of capital and attract responsible investors. Collaborative and ecosystem-based innovation processes, as exemplified by Valmet's Beyond Circularity, provide mechanisms for faster transition through shared risk and resources.

6.8 Synthesis from the Discussion

The four frameworks are not competing but complementing. TBL provides three dimensions - environment, social and economy. ESG operates accountability and performance with the aid of governance mechanism. CE allows resources to flow circularly. LeanGreen highlights the interrelationship between efficiency and environmental performance. From evidence, systemically embedding sustainability in strategy and operation seems to lead to the best results. Responsibility for environment and society, superiority in governance and economic competency complement each other. Empirical results in ABB, Wärtsilä and Valmet indicate that the sustainable transformation for advanced

manufacturing is not sidelining, but strategic, quantifiable, financially oriented, and operationally embedded.

7 Conclusions and Recommendations

This chapter presents the final conclusions depicted from the comparative analysis of sustainability practices at ABB, Wärtsilä, and Valmet. It summarizes key findings, outlines theoretical and practical contributions, provides managerial recommendations, acknowledges limitations and suggests directions for future research.

7.1 Summary of Findings

This thesis aimed to understand how manufacturing companies put sustainability plans into action. It also analyzed whether these companies performed on environmental, social and economic goals simultaneously without degrading their overall performance. This thesis analyzed the sustainability reports from 2022 to 2024 with respect to the Triple Bottom Line (TBL), Circular Economy (CE), and Environmental, Social, and Governance (ESG) frameworks. The three findings that can be concluded are as follows:
Firstly, all three companies have hugely improved their ecological performance. Since 2019, ABB reduced its Scope 1 and 2 emissions by 78%. From 2018, Wärtsilä has decreased material consumption by 45% along with hazardous waste by 51%. Valmet achieved a 49% reduction in emissions with its targets approved by the Science Based Targets initiative (SBTi). These findings suggest that tremendous emissions cuts are possible without industrial loss.

Second, social sustainability has improved steadily in all three companies. Safety performance remained strong. ABB achieved an industry leading Lost Time Injury Frequency Rate (LTIFR) of 0.15. Gender diversity in management has reached 21–22% across the companies. Valmet shows particularly strong performance, with almost equal pay between men and women by –0.23% pay gap and by exceeding its target for diversity in STEM roles by 12.4%. Third, the findings confirm that sustainability reinforces rather than compromises economic performance. ABB's 204 million tonnes of cumulative avoided emissions, Wärtsilä's strategic positioning through zero-carbon fuel

development, and Valmet's EUR 250 million green finance issuance demonstrate that environmental and social investments enhance long-term competitiveness.

7.2 Theoretical and Practical Contributions

This thesis has made several contributions to academic sector. First, the joint usage of TBL and CE and ESG framework provides a more in-depth view of corporate sustainability practices than using only singular framework. Second, it enhances the work on the circular economy by proving that circular benefits can be achieved through operational efficiency improvements for e.g. Wärtsilä. Third, it demonstrates the compatibility of lean with green practices which support advanced frameworks such as Smart, Green, Resilient and Lean (SGRL) manufacturing. At a practical level, the thesis provides industrial managers with benchmarks by revealing sustainability practices, targets and performance across three high-leading companies. The comparative analysis provides a reference for other manufacturers to compare and improve their sustainability performance.

7.3 Managerial Recommendations

Based on the findings, several recommendations are suggested for industrial managers. From a strategy perspective, sustainability needs to become part of the core business strategy. The process should be relied on bold, science-based targets verified by efforts such as SBTi (Science Based Targets initiative). Executives should be incentivized by the company's ESG performance, and the potential role of green financial instruments should be investigated to align sustainability achievements and capital investments.

On the operational level, lean and green efforts should be pursued jointly as efficiency improvements often yield environmental benefits. At an operational level the lean and green objectives can be pursued in conjunction with each other, efficiency gains should lead to environmental gains.

7.4 Limitations of the Study

Several limitations are there in this thesis. First, the thesis covers only three case companies. This limits the scope of thesis from findings of wider manufacturing sector. Second, the analysis relies on publicly available website sustainability reports. These reports may be biased and can have selective disclosure of information. Third, variations of reporting frameworks of the companies and their baseline years make comparison difficult. Plus, the performance metrics are also different for each company, this further made the comparison difficult. Fourth, the thesis focuses only on large multinational corporations situated in Europe. So, sustainability challenges and practices may be different for other companies. Finally, although the three-year timeframe allows for the identification of trends in this part this may not be applicable for long term.

7.5 Suggestions for Future Research

Future researchers could address the limitations of this by expanding their case companies from three to more companies. They can also include longer periods of time that is more than three years. They can also include the data by conducting interviews with the managers to understand their decision-making process. Further research may also include the theoretical understanding lean and green practices elaborately. Researchers could also analyze the uses of digital technologies for circular economy. Moreover, researchers could further explore the relationship between sustainability performance and cost capital.

7.6 Concluding Remarks

This thesis concludes that sustainable manufacturing is achievable and confines the long term strategical advantageous. The result of the case companies' analysis proves that environmental responsiveness, social accountability, excellent governance and financial

performance have a complementary and reinforcing relation to each other. This thesis also offers valuable lessons for academic literature and industrial practices. Sustainability in advanced manufacturing is no longer peripheral or reputational. In today's scenario, sustainability practices are more strategic, financially integrated and operationally embedded. The companies that embrace this transformation will be best positioned to succeed in the increasingly sustainability-focused economy of the future.

References

ABB. (2024a). Integrated Report 2024. ABB Ltd.

ABB. (2024b). Sustainability Statement 2024. ABB Ltd.

Bonfanti, A., Mion, G., Brunetti, F., & Vargas-Sánchez, A. (2022). The contribution of manufacturing companies to the achievement of sustainable development goals: An empirical analysis of the operationalization of sustainable business models. Business Strategy and the Environment, 2490–2508. https://doi.org/10.1002/bse.3260

Bryman, A. (2016). Social research methods (5th ed.). Oxford University Press.

Bello-Pintado, A., Machuca, J. A. D., & Danese, P. (2023). Stakeholder pressures and sustainability practices in manufacturing: Consideration of the economic development context. *Business Strategy and the Environment*, *32*(7), 4084–4102.

Creswell, J. W., & Poth, C. N. (2018). Qualitative inquiry and research design: Choosing among five approaches (4th ed.). SAGE Publications.

Deirmentzoglou, G. A., Anastasopoulou, E. E., Masouras, A., & Symeou, P. (2026). Environmental, social, and governance (ESG) factors in international trade: A systematic review and integrative framework. Sustainability, 18(2), 677. https://doi.org/10.3390/su18020677

Domingo, R., & Aguado, S. (2015). Overall environmental equipment effectiveness as a metric of a lean and green manufacturing system. Sustainability, 7(7), 9031-9047. https://doi.org/10.3390/su7079031

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. Qualitative Health Research, 15(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Karuppiah, K., Sankaranarayanan, B., & Lo, H. W. (2024). A systematic literature review on the evolution of sustainable manufacturing practices: Key findings and implications. Cleaner Engineering and Technology, 22, 100798. https://doi.org/10.1016/j.clet.2024.100798

Koch, D., & Sauer, A. (2024). Identifying and Dealing with Interdependencies and Conflicts between Goals in Manufacturing Companies' Sustainability Measures. Sustainability, 1-18. https://doi.org/10.3390/su16093817

Lincoln, Y. S., & Guba, E. G. (1985). Naturalistic inquiry. SAGE Publications.

Nica, I., Chiriță, N., & Georgescu, I. (2025). Triple bottom line in sustainable development: A comprehensive bibliometric analysis. Sustainability, 17(5), 1932. https://doi.org/10.3390/su17051932

Opoku, R. K., & Li, X. (2025). Sustainable management practices, operational and sustainable performance in manufacturing contexts: empirical evidence from a developing economy. Journal of Responsible Production and Consumption, 2(1), 48-82. https://doi.org/10.1108/JRPC-07-2024-0035

Purushothaman, R., Alamelu, R., Selvabaskar, S., & Sudha, M. (2025). Theories, techniques and strategies of sustainable circular economy: A systematic literature review. Discover Sustainability, 6(1), 297. https://doi.org/10.1007/s43621-025-01161-5

Setyadi, A., Pawirosumarto, S., & Damaris, A. (2025). Embedding circular operations in manufacturing: A conceptual model for operational sustainability and resource efficiency. Sustainability, 17(15), 6737. https://doi.org/10.3390/su17156737

Tiuncika, L., & Bormane, S. (2024). Sustainable management of manufacturing processes: A literature review. Processes, 12(6), 1222. https://doi.org/10.3390/pr12061222

United Nations Industrial Development Organization. (2025). Clean energy and climate action in industry: Pathways to 2050. unido.org

Valmet Oyj. (2024a). Annual Review 2024. Valmet Oyj.

Valmet Oyj. (2024b). Sustainability Statement 2024. Valmet Oyj.

Verrier, B., Rose, B., & Caillaud, E. (2016). Lean and green strategy: The lean and green house and maturity deployment model. Journal of Cleaner Production, 116, 150-156. https://doi.org/10.1016/j.jclepro.2015.12.022

Viles, E., Cavallieri, M., Kalemkerian, F., Montoya-Torres, J., & Santos, J. (2023). Assessing sustainable production: A selection of indicators aligned with the SDGs. Sustainable Development, 1-19. https://doi.org/10.1002/sd.2793

Wärtsilä Corporation. (2024a). Annual Report 2024. Wärtsilä Corporation.

Wärtsilä Corporation. (2024b). Sustainability Statement 2024. Wärtsilä Corporation.

Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). SAGE Publications